3.5.2 River System

Pasig-Marikina River System

The Pasig-Marikina River flows through the City of Manila to the Manila Bay. Its total catchment area is estimated at about 635 km^2, about 10% of which is situated in Metro Manila.

The Mangahan Floodway has been constructed to discharge water from the Marikina River into the Laguna Lake at the design discharge of 2,400 m^3/s with the Marikina Control Gate Structure (MCGS) which is yet to be completed. In this situation, a discharge of 1,100 m^3/s is designed to flow down the lake when the Marikina River has a discharge of 2,000 m^3/s.

At the confluence with the Napindan Channel, the river is known as the Marikina River in the upper reaches and the Pasig River in the lower reaches. The San Juan River, one of the tributaries with a catchment area of 91 km^2, joins the Pasig River at its meandering section in the central city area. Napindan River, the only outlet of the Laguna Lake, topographically belongs to the Laguna Lake Basin.

Malabon-Tullahan River System

The Malabon-Tullahan River System originates in the northeastern boundary of Metro Manila and flows into the Manila Bay. The main stream of this river system is called by different names such as Tullahan, Tenejeros, Malabon and Navotas depending on the location from the upstream to the downstream. The Novaliches Reservoir, the municipal and industrial water source for Metro Manila, is located in the upper reaches of this river system.

Buli-Baho-Mahaba River System

All of the rivers located to the west of the Mangahan Floodway have a rather steep riverbed gradient and they collect runoff from the mountainous and hilly land. The lower stretches do not have enough flow capacities, so that runoff water, together with the water from the Laguna Lake during high lake stage, inundates the flat lowland area.

South Parañaque-Las Piñas River System

This river system is situated in the southern part of Metro Manila. The South Parañaque River flows for about 3.0 km along the seashore from the southern end of Estero Tripa de Gallina to Manila Bay.

At the vicinity of the estuary, two tributaries, the Dongalo and the San Dionisio rivers, join the South Parañaque River. The Las Piñas River joins the Paranaque River and the Zapote River in the low-lying area adjacent to the seashore.

3.5.3 Drainage Areas

The drainage areas which suffer from flooding due to inland water were identified on the basis of the flood survey and the topograhical study. These areas account for 217 km^2 of the study area and can be divided into nine (9) areas, as shown in Fig. 3.1-1.

Manila and Suburbs

Manila and Suburbs, which cover 7,172 ha, is divided into two areas by the Pasig River; namely, North Manila and Suburbs (2,858 ha) and South Manila and Suburbs (4,314 ha). A drainage system consisting of pumping stations and box culverts has been installed, based on the Master Plan Study called the "Plan for the Drainage of Manila and Suburbs" which was prepared by the Bureau of Public Works (now, DPWH) in 1952.

The drainage methods can be classified broadly into two (2); namely, pump drainage and gravity flow drainage. Based on the drainage method and the point of discharge, North Manila and Suburbs is divided into 10 drainage districts which are the further divisions of subdrainage areas, while South Manila and Suburbs is divided into 11, as shown in Fig. 3.5-1. The drainage method in the respective districts is tabulated in Table 3.5-1.

At present, there exist 10 pumping stations with the total capacity of 173.8 m^3/s, covering 10 low-lying drainage districts of 4,192 ha or 58% of the Manila and Suburbs drainage area. The remaining area of 2,980 ha is drained by gravity flow.

The main drainage channels in Manila and Suburbs consist of open channels and box culverts. Open channels are called "esteros" and their widths vary from 6 m to 70 m. Box culverts, the size of which is generally more than 3.0 m in width and 2.0 m in depth, are classified into two (2) types; namely, drainage mains and outfalls. Outfalls are special culverts which connect Manila Bay or the Pasig River with the esteros to drain floodwaters by gravity flow, while the other culverts are called drainage mains. The features of major esteros, drainage mains and outfalls are tabulated in Table 3.5-1. Laterals are installed in the main roads of this area at the density of 6,000 m/km^2.

Malabon-Navotas

This area has 2,492 ha located along the Tullahan-Malabon-Navotas River. Ring dikes have been constructed along some portions of the Malabon-Navotas River and other creeks to protect the area from inundation, particularly, due to high tide, but the height is not sufficient. The creeks running in this area serve as the drainage channel; laterals are installed on the density of 2,400 m/km^2, except for Dagat-Dagatan.

As for Dagat-Dagatan, the area can be broadly divided into four drainage districts; namely, Kapitbahayan, Spine, Saluysoy and Maypajo, as shown in Fig. 3-5-2. The drainage area of the districts are estimated at 91 ha, 164 ha, 97 ha, and 115 ha, respectively.

Drainage is done by gravity flow in all areas of Dagat-Dagatan. Main drainage channels of mostly concrete flume which are called "drain" are installed in three drainage districts except Kapitbahayan which has only the drainage laterals. The features of main drainage channels are tabulated in Table 3.5-1.

East of Mangahan

This area is the lowest portion of Buli, Baho and Mahaba river basins situated just east of the Mangahan Floodway. The size of the area is 876 ha. This area is believed to be affected by the high water level of the Laguna Lake.

The drainage system found in this area is one lateral installed on a main road, though the subdivisions constructed in this area have their own drainage systems.

West of Mangahan

This area covers 3,814 ha and is surrounded by the Pasig River, the Mangahan Floodway and the Laguna Lake. This area is also affected by the high water of the Laguna Lake. Small rivers run into the Laguna Lake, in addition to the Napindan, the Antipolo and the Tipas rivers, and function as the main drainage channel. Laterals are few in this area.

San Juan

The area which is judged to have inland water problems in the San Juan River Basin is the area of 1,260 ha located near the river. The main drainage channels are tributaries of the San Juan River. There are some laterals in this area.

Mandaluyong-Pasig

This is a narrow area of 1,525 ha located along the Pasig River and the Marikina River in the municipalities of Mandaluyong and Pasig. The principal drainage channels are three (3) open channels called creek. The laterals are installed in main roads in this area on the density of 690 m/km^2.

Marikina

This is also a narrow area of 1,168 ha in Quezon City and the municipality of Marikina on both sides of the Marikina River. In this area, drainage channels including laterals are poorly distributed.

Parañaque-Las Piñas

This is the low area of 1,543 ha located along the Manila Bay. The Parañaque and the San Dionisio rivers running along the coast function as the principal drainage channels.

Since water is pumped out from the Tripa de Gallina Pump Station to the Parañaque River, three (3) outfalls; namely, Rivera, Librada and

Seaside, have been installed from the Parañaque River to the Manila Bay to drain the floodwaters. The laterals are installed on a density of 350 m/km^2 and 300 m/km^2 in Parañaque and in Las Piñas, respectively.

Valenzuela

This is located near the Meycauayan River covering an area of 1,842 ha. Ring dikes have been constructed along the Meycauayan River and the creek running to the west of this area, but the height is insufficient. At present, most of the area is used as fishpond; therefore, no drainage system is found, except the small rivers running along the coast.

3.6 Existing Flow Capacity

3.6.1 River System

Calculation Conditions

- Equation for Flow Capacity Estimation: Non-Uniform Flow Calculation Method

- Roughness Coefficient : 0.03

- Hydraulic Boundary Conditions : 11.30 m (Mean Spring High Tide) for Manila Bay Tide

  : 12.50 m (Annual Highest Mean) for Laguna Lake Level

Flow Capacity Estimates of River Channel

(1) Pasig-Marikina River

The flow capacities of the Pasig River, the Marikina River, the San Juan River and the Napindan Channel are discussed herein in connection with the Pasig-Marikina River System.

The Pasig River is divided into two stretches, the stretch from the river mouth to the confluence with San Juan River and the stretch from the confluence to the Napindan junction. The bankfull flow capacity is estimated at 700 m^3/s in the stretch from the river mouth to the San Juan River and 500 m^3/s in the stretch from the San Juan River to the Napindan junction.

The Marikina River is divided into two stretches, the Lower Marikina River from the Napindan junction to the diversion point of the Mangahan Floodway and the Upper Marikina River in the upper reach from the diversion point of the floodway. The bankfull flows of the two stretches are about 500 m^3/s for the Lower Marikina River, and in the Upper Marikina River, 1,100 m^3/s from the diversion point of the floodway to Sto. Niño and about 1,500 m^3/s from Sto. Niño to Montalban.

The bankfull discharge of the San Juan River is estimated at only 50 m^3/s.

The bankfull flow of the Napindan River from the Laguna Lake to the Pasig River is only about 50 m^3/s because the bank height in the stretch of about 4 km from the lake is very low.

(2) Malabon-Tullahan River

The stretch of the Malabon-Tullahan River about 5 km upstream from its river mouth is affected by the tidal fluctuation, and its bankfull flow capacity is almost nil at the mean spring high tide. The middle stretch of the Malabon River which is called the Tullahan River, has a rather steep riverbed gradient of about 1/100 which provides a flow capacity of about 100 m^3/s only at mean sea level.

The Navotas River runs along the seashore; therefore, the whole river stretch is affected by tidal fluctuations and the bankfull flow capacity is almost nil at the mean spring high tide. The Malabon River is under the same condition.

(3) Buli-Baho-Mahaba River

The flow capacity of the river is fairly influenced by the water stage of the Laguna Lake. Subject to the lake stage of 12.5 m which corresponds to the annual mean highest stage, the estimated bankfull flow capacities of the rivers are 30 m^3/s along the Buli River, 50 m^3/s

along the lower reaches of Baho River, 20 m^3/s along the upper reaches of Baho River, and 5 m^3/s along Mahaba River.

(4) South Parañaque-Las Piñas River

In the Parañaque and Las Piñas area, there are three major rivers; namely, South Parañaque, Las Piñas and Zapote, which cause serious flooding by river channel overflow. In the South Parañaque River and its major tributary, the Dongalo River, the lower and middle reaches are affected by the tidal fluctuation. Thus, the bankfull flow capacity is almost nil when the tidal level of the Manila Bay rises to around its mean spring high tide of 11.30 m.

In the Las Piñas and the Zapote rivers, the stretch of about 5 km from the river mouth is affected by the tidal fluctuation. During high tide in Manila Bay, the bankfull flow capacity in the downstream of Las Piñas River is almost nil and the middle stream will have about 10 m^3/s of the bankfull flow capacity.

San Dionisio and Parañaque rivers interconnect the aforementioned three rivers. Since the rivers run on flat and low land, the flow capacity is almost nil when the tidal level is high.

3.6.2 Drainage System

Two areas in Metro Manila have been provided with drainage systems in accordance with their own master plans. These areas are the Manila and Suburbs Drainage Area and the Dagat-Dagatan in the Malabon-Navotas Drainage Area. The capacity of these systems have been evaluated.

Calculation Conditions

(1) Equation for Flow Capacity Estimation

(a) For Open Channel

- Non-Uniform Flow Calculation Method

(b) For Culvert

Uniform flow calculation when the water level at the outlet is lower than or equal to 90% of the depth of drainage main/outfall and pressure flow calculation when the water level at the outlet is higher than 90% of the depth of drainage main/outfall.

(2) Roughness Coefficient

(a) For Open Channel : 0.030

(b) For Culvert : 0.015

(3) Hydraulic Boundary Condition

The drainage channels are classified into two types from the viewpoint of drainage method; namely, the channel without pumping station which drains flood water by gravity flow and the channel with pumping station at its downstream end.

(a) For Channel Without Pumping Station

The higher water level between the Design High Tide (EL 11.80 m) and the Design Water Level at the outlet.

(b) For Channel With Pumping Station

Pump Starting Water Level (PSWL) and Mean Spring High Tide EL 11.30 m.

Flow Capacity Estimate of Drainage Facilities

The capacity of existing drainage facilities, namely pump stations and principal drainage channels, are discussed hereinafter, comparing with the required pump capacity and peak discharge for 10-year and 5-year return periods.

(1) Manila and Suburbs

The capacity of existing facilities is tabulated in Table 3.6-1. For convenience, the tentative names for drainage districts given before are also used. The following are the explanations on the capacity of existing drainage facilities of all the drainage districts.

(a) Sunog Apog

The principal drainage channels are Estero de Vitas, Sunog Apog, Maypajo and Blumentritt Interceptor. The left bank of Estero de Vitas is lower than the Design High Tide around the junction with Estero de Sunog Apog. The survey was not conducted for Sunog Apog and Maypajo but their capacity is estimated at 56 m^3/s and 35 m^3/s, respectively, according to the data described in the Appendices of Preliminary Alternative Master Plan Strategy Report for the Metro Manila Integrated Urban Drainage and Flood Control Master Plan (hereinafter referred to as the E/S Report) and so on. These two esteros have the capacity of less than a 5-year return period.

The outlet of Blumentritt Interceptor is low and thus the pressure flow condition is estimated to occur when the sea level is EL 11.80 m. Blumentritt Interceptor can convey 20.0 m^3/s under the pressure condition, which is lower than a 5-year return period flood discharge.

(b) Vitas

The principal drainage channels consist of Estero de Vitas and Estero de la Reina. The flow capacity of Estero de Vitas is 50 m^3/s and that of Estero de la Reina is 20 m^3/s. The flow capacity is smaller than a 5-year return period flood in all reaches.

(c) Balut

In this area, the laterals are the existing drainage facilities.

(d) Northeast Pasig

The laterals are the existing drainage facilities.

(e) Valencia P.S.

The principal drainage channels are Estero de Valencia and Visayas Main. The flow capacity of Estero de Valencia was estimated at 30 m^3/s based on the E/S Report, etc., and this is smaller than a 5-year return period flood. Visayas Main can convey a runoff discharge of 18 m^3/s, corresponding to almost a 10-year return period under pressure flow condition. The capacity of the Valencia Pumping Station is less than a 5-year return period flood.

(f) Aviles-Sampaloc P.S.

Estero de Sampaloc and San Miguel are principal open drainage channels. Lepanto-Gov. Forbes Main connects with Estero de Sampaloc and two drainage mains; namely, Lepanto-Josephina Main and Economia Main. The Aviles-Sampaloc Pumping Station has a capacity of almost a 5-year return period.

Estero de San Miguel has a small cross section; thus, the flow capacity is 5 m^3/s and less than a 5-year return period flood. For Estero de Sampaloc, the cross sectional data in 1988 is not available but the flow capacity is estimated at 40 m^3/s based on the E/S Report, etc., and this is a little bit smaller than a 5-year return period flood.

Judging from the elevation of outlets of drainage mains, Lepanto-Gov. Forbes and Lepanto-Josephine Mains can drain water in the open channel condition, while Economia Main is in the pressure condition. Out of the three drainage mains, only Lepanto-Gov. Forbes Main can convey a 10-year return period flood. The other drainage mains have the capacity of less than a 5-year return period.

(g) Quiapo P.S.

In this drainage district, the principal open channels are Estero de Quiapo and San Miguel, while the drainage main is Severino Reyes. The flow capacity of Estero de Quiapo and San Miguel are 40 m^3/s and 20 m^3/s, respectively. The design flow capacity of Severino Reyes is 7 m^3/s under pressure condition. Among these channels, Esteros Quiapo and San Miguel have the capacity almost equal to a 10-year return period flood, while the drainage main has less than a 5-year return period. The capacity of Quiapo Pumping Station is between a 5-year and a 10-year return period flood.

(h) Binondo P.S.

The principal drainage channels are Estero de Binondo and Estero de la Reina. During pump operation, water of Reina flows in reverse. The flow capacity of Estero de Binondo is a little bit smaller than a 5-year return period. Estero de la Reina has the small flow capacity of less than a 5-year return period, especially in reverse condition which is less than the pump capacity. The pump capacity of Binondo Pumping Station is also less than a 5-year return period.

(i) Northwest Pasig

In this area, the laterals are the existing drainage facilities.

(j) North Manila Bay

The principal drainage channels are two drainage mains; namely, Pacheco and Lakandula. The outlets of both mains are submerged when the sea level rises at 11.8 m. Under the pressure condition, Lakandula Main can convey a 10-year return period flood, while Pacheco Main has a capacity of less than a 5-year return period.

(k) Makati Slope

Zobel Orbit Outfall is the principal drainage channel which drains flood water into the Pasig River by gravity flow. For this channel, the design high water level of the Pasig River at its outlet (EL 14.0 m) is used as the hydraulic boundary condition. Under this water level, pressure flow condition occurs and flow capacity is about equal to a 10-year return period discharge.

(l) Makati P.S.

The principal drainage channels are Makati Headrace No. 1 and No. 2, which have enough capacity to convey a 10-year return period discharge. The pump capacity is also of the same degree of safety.

(m) Sta. Clara P.S.

Estero de Sta. Clara which is the only principal channel in this drainage district has a capacity to convey a discharge equivalent to the pump capacity of 5.3 m^3/s. The capacity of the Sta. Clara Pumping Station is less than a 5-year return period flood.

(n) San Andres

The principal drainage channels are Estero de Pandacan, Tripa de Gallina, Tributary of Tripa de Gallina and Vito Cruz Outfall. The flow capacity is too small in Estero de Pandacan (3 m^3/s) and Tripa de Gallina (5 m^3/s) compared with a 5-year return period flood. As for the tributary of Tripa de Gallina, no cross sectional data is available. Vito Cruz Outfall can convey 4 m^3/s under pressure flow condition when the tide level is EL 11.80 m.

(o) Pandacan P.S.

Estero de Pandacan is the principal drainage channel with a flow capacity of 15 m^3/s. This capacity is bigger than the pump capacity but smaller than the peak discharge of a 5-year return period. The pump capacity is less than a 5-year return period.

(p) Paco P.S.

The principal channels are Estero de Paco and Concordia. The flow capacity of the down reaches of Paco is enough to drain a 10-year return period flood, while the middle and upper reaches have the capacity lesser than a 5-year return period flood. The pump capacity of the Paco Pumping Station is less than a 5-year return period.

(q) Balete

The existing drainage facilities are laterals.

(r) Southwest Pasig

The laterals are the existing drainage facilities.

(s) South Manila Bay

Two drainage mains have been installed; namely, Padre Faura and Remedios. The outlets of both mains are high and so open channel flow occurs for the Design High Tide. Both drainage mains can drain a 10-year return period flood.

(t) Libertad P.S.

The principal drainage channels are Estero Tripa de Gallina, Zobel-Roxas Main and three (3) outfalls, namely Buendia-Roxas, Libertad and EDSA. The flow capacity of Estero Tripa de Gallina between Zobel-Roxas Drainage Main and Buendia-Roxas Outfall is too small compared with the discharge corresponding to the pump capacity. On the other hand, one drainage main and three outfalls have the flow capacity equal to a 10-year return period. The flow condition of Zobel-Roxas is pressure flow, but outfalls are considered to be in open channel flow condition since the water level at pumping stations is kept to be low due to the large retarding pond and low pump starting water level. The pump capacity of the Libertad Pumping Station exceeds a 5-year return period flood.

(u) Tripa de Gallina P.S.

Estero Tripa de Gallina and the Delain Creek are the principal drainage channels. Tripa de Gallina between the EDSA Outfall and the Delain Creek has the capacity of more than a 10-year return period flood, while the other stretches have less than a 5-year return period flood. As for the Delain Creek, no data is available. The Tripa de Gallina Pumping Station has the capacity of more than a 5-year return period flood.

(2) Dagat-Dagatan

In Dagat-Dagatan, drainage can be done by gravity flow due to the rather high elevation of the land. The following are the comparison of the capacity of drainage channels with peak discharges of 10-year and 5-year return period.

(a) Spine

The flow capacity of the main drainage channel of Spine is 25.8 m^3/s, which is a little bit smaller than a 10-year return period flood (26.3 m^3/s) but bigger than a 5-year return period flood (23.6 m^3/s).

(b) Saluysoy

The Saluysoy channel has the flow capacity of 17.4 m^3/s, which is also a little bit smaller than a 10-year return period flood (17.7 m^3/s) but bigger than a 5-year return period flood (15.9 m^3/s).

(c) Maypajo

There are two main channels called Northern Drain and Southern Drain which are connected to Estero North Sunog Apog. The capacity of these channels are 10.9 m^3/s and 3.0 m^3/s, respectively, which are less than a 5-year return period. However, in both the drainage areas, floodwaters of some 50% of the areas are designed to be drained into Estero North Sunog Apog through laterals, therefore, the two main channels can convey a 5-year return period flood from the remaining areas.

(d) Kapitbahayan

In this area, laterals are the existing drainage facilities.

Evaluation of Drainage Facilities

(1) Manila and Suburbs

Two main drainage facilities in Manila and Suburbs, namely main drainage channels and pump stations are evaluated hereunder.

According to the flow capacity of drainage channels mentioned before, the main drainage channels in 6 of the 16 drainage districts have the capacity that is almost equivalent to a 10-year return period flood at their lower reaches, while those in the other 10 drainage districts have the capacity lower than a 5-year return period flood.

Main drainage channels in 3 of the 10 drainage districts, namely Vitas, San Andres and Sunog Apog will be improved into a safety degree of 10-year return period, together with the construction of the 3 pumping stations mentioned below under the Metro Manila Flood Control Project. Prior to this project, the Project for Retrieval of Flood Prone Areas in Metro Manila will be implemented to dredge esteros and to declog the drainage mains/outfalls and laterals in all the drainage districts of Manila City (17 drainage districts). Under these projects, main drainage channels in 5 of the 10 drainage districts will be dredged and declogged. It is expected that the dredging and declogging work will contibute to the restoration of their original flow capacity which may be a 10-year return period judging from the design safety degree of pump stations and drainage main/outfalls.

Regarding pump stations, of the 10 drainage districts with pumping stations, 5 drainage districts have pumps with the capacity exceeding a 5-year return period and 5 have the capacity lower than a 5-year return period.

There are 5 drainage districts presently under the gravity drainage method that need the construction of pumping stations. In 3 of these 5 drainage districts, namely Vitas, Balut and San Andres, pumping stations will be constructed with the safety degree of a 10-year return period, together with the improvement of related drainage channels, under the Metro Manila Flood Control Project. The following table shows the total pumping capacity in Manila and Suburbs, together with the pumping capacity required for 10-year and 5-year return period floods.

(Unit: m^3/s)

Item	North Manila & Suburbs	South Manila & Suburbs	Manila & Suburbs (Total)
Present Pump Capacity	45.5	128.3	173.8
Capacity of Planned Pumping Stations	33.8 (Vitas 31.8) (Balut 2.0)	17.4 (San Andres)	51.2
Total	79.3	145.7	225.0
Pump Capacity for 10-year Return Period	103.9	169.1	273.0
Pump Capacity for 5-year Return Period	82.7	135.6	218.3

After completion of the Metro Manila Flood Control Project, the total pumping capacity in Manila and Suburbs will reach 225 m^3/s, which will exceed the pumping capacity required for a 5-year return period flood. In addition to the increment in pumping capacity, the flow capacity of the drainage channels in Manila and Suburbs will be improved under the two projects mentioned before, so that Manila and Suburbs will have the highest level of safety against inland water flooding compared with the other 8 drainage areas.

(2) Dagat-Dagatan

In this area, all main drainage channels (drains) have the capacity of more than a 5-year return period. To raise the safety degree in this area to a 10-year return period, the construction of small channels (laterals) are enough even in the two drainage districts of Spine and Saluysoy where the runoff discharge is large, because the capacity of main drainage channels is these two drainage districts is almost equal to a 10-year return period.

3.7 Water Quality

3.7.1 Water Quality in Major River Channel

Pasig-Marikina River

(1) Pasig River

The Pasig River has been classified as Class "C" water body which is intended for the propagation and growth of aquatic life by the Government of Philippines (refer to Table 3.7-1). However, the average concentration of water quality of the river during the period from 1982 to 1987 has shown high contaminated conditions, especially organic pollution. For example, the average of annual mean values of BOD in the rainy season from 1982 from 1982 to 1987 are more than 20 mg/l only, except for Bambang, and DO are less than 5 mg/l at all monitoring stations. In the dry season, the concentration of BOD shows about 30 mg/l, slightly higher than that of the rainy season.

(2) Marikina River

The upper most area of the Marikina River is designated Class "A" and the lower is Class "C". The water quality at Montalban, which is located at the most upper area among three major monitoring stations, shows very clean and uncontaminated conditions mainly due to little discharge of domestic sewage and to active self-purification under the anaerobic conditions. However, the concentration at the downstream stations becomes high and shows considerably contaminated condition of the river water. The average of annual mean values of BOD is about 20 mg/l, and it is almost the same as that at Guadalupe in Pasig River. There is no considerable difference in BOD between the dry season and the rainy season.

(3) San Juan River

San Juan River is one of the tributaries of the Pasig River and it has heavily contaminated condition conditions. The annual mean values of DO in the rainy season at four monitoring stations are almost 0 mg/l, and the concentration of BOD is about 50-60 mg/l, nearly two or three times higher than that of Pasig River. Moreover, BOD values in the dry season are about 70-80 mg/l, considerably higher than those of the rainy season. Therefore, it is considered that the water in the San Juan River is almost under the anaerobic condition all year long, and it is very hard to attain the compliance of Class "C".

Malabon-Tullahan River

The Malabon-Tullahan River is a 26 km long waterway that runs from the La Mesa Reservoir in Novaliches emptying into Manila Bay. The continuous and indiscriminate dumping of all kind of wastes to the river has resulted in murky water with a foul odor, heavy siltation and extinction of aquatic life. Now this river is the most polluted in Metro Manila especially at the middle reach area. The average concentration of DO in the rainy season is almost 0 mg/l, and BOD is about 40-50 mg/l at North Expressway, MacArthur Highway and Governor Pascual. In the dry season, the river shows heavier contaminated condition, BOD is almost 60 mg/l, compared with the rainy season. At present, there is no classification in this river.

Buli-Baho-Mahaba River

The Baho, Buli and Mahaba rivers which flow into the Laguna Lake, are located in the east side of the Mangahan Floodway. At present, there are no data related to water quality of the rivers. Water quality is currently considered to be in heavily deteriorated condition due to the discharge of untreated wastewater to the rivers as determined from the interview survey and field reconnaissance by the Study Team.

South Parañaque-Las Pinas River

The South Parañaque River flows from the southern part of Estero Tripa de Gallina to Manila Bay, and the Las Piñas River joins the South Parañaque River and the Zapote River in the low-lying area adjacent to the seashore. The water quality at the monitoring stations which are located near Manila Bay, show the relatively clear condition than those of the inland area. Although the South Parañaque River and the Zapote River are both designated the water bodies of Class "C", the concentration of BOD of the South Parañaque River is about 30-40 mg/l, and it is higher than the criteria of Class "C". Though the values of

BOD in the dry season are higher than those of the rainy season, the difference is not so big.

Laguna Lake

Laguna Lake is a shallow lake, average water depth is about 3 m, immediately inland from Metro Manila. It serves as a natural detention reservoir for discharges from the Pasig River, the Marikina River and the surrounding tributaries of the lake. The LLDA is undertaking water quality monitoring program at four monitoring stations on the lake. The existing lake water quality is rather clean with a high concentration of DO (7-8 mg/l) and low of BOD (2-3 mg/l). It complies with the designated criteria of Class "C".

3.7.2 Water Quality in Drainage Channel

The water quality of estero and creeks is quite different in the rainy season and the dry season. In the rainy season, the mean concerntration of BOD in estero is about 13 mg/l, which is lower than that of the Pasig River. On the other hand, heavily polluted conditions, the mean concentration of BOD is about 70 mg/l, can be found during the dry season. Especially, the concentration of BOD of Estero de Paco, Estero de Valencia, and Estero Tripa de Gallina are over 100 mg/l, mainly due to dimishing flash out and dilution effects of polluted water in esteros.

3.8 Flooding Condition

3.8.1 Frequency and Inundation Area of Flooding

Metro Manila suffers from serious flood damage in 1948, 1966, 1967, 1970, 1972, 1977, 1986 and 1988. Floods were caused by overtopping of the main rives as well as inland water. Once this type of flooding occurs, low-lying areas in Metro Manila along the Manila Bay and the Laguna Lake are totally submerged. In addition to this type of flooding, local inundation takes place at a number of low-lying spots in every heavy rain.

Flooding in 1986 caused by Typhoon Miding inflicted the most serious damage in recent years to Metro Manila. The NCR Engineering District Offices conducted a survey on the September 1986 flood in cooperation with the JICA Study Team in March 1988. The flood area in Metro Manila reached 86.7 km^2, 14.5% of Metro Manila. When the flooded area of Cainta and Taytay located in the Marikina Valley are included, the total flooded area was 103.6 km^2 as shown in Fig. 3.8-1.

Flooding in 1988 caused by Typhoon Unsang also inflicted serious damage in the Marikina Valley and in the low-lying shoreline area of the Laguna lake because of the overflowing flood water of the Marikina River and the incremented high lake stage. Especially the village of Provident Subdivision located at the right bank side in the lower reach of Sto. Niño was damaged tremendously because of the destruction of the river wall by the flood flow.

3.8.2 Causes of Flooding

The area of Metro Manila is covered with the active/former tidal flats along the Manila Bay including the part of Manila City, alluvial plain from Marikina to Laguna and tuff plateau running from north to south in the middle part of Metro Manila. It is basically situated where the topography is vulnerable to flooding aggravated by a combination of the following major causes:

Cause	Results
Rapid large-scale urbanization	Creation of new impervious areas with higher peak runoff
Poor capacity of river channels	Overbanking of river water
Poor capacity of drainage facilities	Creation of local inundaiton portions
Poor maintenance of drainage facilities	Reduction of drainage capacities by blockage with silt, garbage, vegetation, etc.
Squatters establishment	Blocking water flow and access for maintenance
Institutional problems and financial restraint	Delay of prompt implementation of countermeasures

3.9 Fund Availability

The following factors were considered in estimating the financial allocation for flood control and drainage works in Metro Manila.

- Estimate of growth of the Philippine economy.
- Forecast of GDP.
- Forecast of the government's development expenditure.
- Forecast of fiscal revenue.
- Budget allocation to DPWH.
- Regional allocation to NCR of DPWH's budget for flood control and drainage works.

The forecast of the Philippine economy from 1990 to 2020 was made by analyzing the impact of the size of debt on the economy, or the economic performance of the past. Economic growth rates for a long term are considered as follows, although a 6.8% growth rate is expected during 1987-92.

- 3% per annum by taking it into consideration to alleviate debt burden on the economy.

- 4% per annum based on past performance consisting of stable and unstable periods.

- 5% per annum based on the stable period in the past.

The growth rate of 3% strongly reflects the restriction of the debt issue on the future economy, and the growth rate of 5% will be difficult to achieve continuously for a long time. For these reasons, 4% per annum is adopted as the growth rate to be actually obtainable.

After the GDP was projected, the size of development expenditure was estimated using the average rate of investment to the GDP and the average rate of development expenditure to gross investment during the observation period from 1971 to 1986. The tax portion of the fiscal revenue was estimated simply by multiplying the tax flexibility with the economic growth. The portion of non-tax was estimated by the proportion of non-tax to tax.

The institutional (DPWH) share of development expenditure was estimated on the basis of actual rate of DPWH's expenditure to the total development expenditures during 1981-86. The rate of investment allocation to DPWH was calculated at 15.5% on the average.

The regional allocation of DPWH's budget on flood control and drainage works in NCR was estimated on the basis of expenditures on obligation basis during 1978 to 1986. This will tend to overestimate the spending allocation to DPWH since actual expenditure was less than the obligation basis. The regional allocation of DPWH's investment to NCR is about 16% on the average, while the sectoral allocation of investment to flood control and drainage works in NCR is about 25%.

Table 3.9-1 shows the annual public investment on flood control and drainage works in NCR by economic growth rate. The figures on this table are expressed at the 1988 constant price. In case the growth rate is 4% per annum, the accumulated amount of public funds up to the year 2020 is estimated at 14.06 billion pesos.

CHAPTER 4. BASIC CONCEPT OF PROJECT FORMULATION

Three plans are to be formulated in this study; namely, the Framework Plan, the Master Plan and the Priority Project. The main planning criteria and conditions include target completion year, coverage area, land use conditions, design return period of flood, and financial conditions as shown in Table 4.1-1.

4.1 Framework Plan

The Framework Plan covers the whole area of Metro Manila and the municipalities of Cainta and Taytay. It presents the outline of the future comprehensive flood plain management for these areas after full urbanization has been attained. This plan could serve as a guide in planning a project master plan with a smaller scale.

The project scale adopted for entire stretches of rivers is a 100-year return period flood, while it is a 10-year return period flood for all the drainage systems. The runoff ratio for each sub-basin was estimated on the basis of land use conditions at the year 2020, which may be the most distant future possible to predict land use. Financial aspects were not considered and no definite design period was set.

4.2 Master Plan

Since the whole Framework Plan is maybe impractical due to financial constraints, the Master Plan was formulated within the financial capacity of the organization concerned by applying a lower degree of safety from flooding or varying the design return period according to the river course and drainage area.

4.3 Priority Projects

Within the framework of the Master Plan, priority projects will be formulated for river courses and/or drainage areas that are now very vulnerable to flood damage and thus require urgent countermeasures against flooding. The planning criteria for priority projects consist, among others, the design period of 2000 and the conditions of present land use for the benefit calculation.

In order not to duplicate the same kind of works, the degree of safety and design runoff discharge are, in principle, the same as those of the Master Plan that will be completed by 2020. The projects are expected to be implemented within the present financial limitations.

CHAPTER 5. FRAMEWORK PLAN

5.1 Premises and Conditions for the Study

In accordance with the study results on the existing condition of the area and the basic study and analysis as mentioned before, the Framework Plan is studied on the basis of the premises and conditions discussed in Chapter 4. These premises and conditions are described more in detail as follows.

Target Completion Year

The target completion year for the Framework Plan is not specified, but it concerns the far future, because this plan presents the outline of the future comprehensive flood plain management for Metro Manila and some of its neighboring areas after full urbanization has been attained.

Study Area

The Framework Plan is prepared for the following rivers and areas (refer to Figs. 3.1-1 and 3.4-1).

(1) River System

- Pasig-Marikina River including San Juan River
- Malabon-Tullahan River
- Buli-Baho-Mahaba River
- South Parañaque-Las Piñas River

(2) Drainage Area

- Manila and Suburbs
- Malabon-Navotas
- East of Mangahan
- West of Mangahan

- San Juan
- Mandaluyong-Pasig
- Marikina
- Parañaque-Las Piñas
- Valenzuela

The study on the Meycauayan River and the Zapote River, which are located at the northern and the southern boundaries of Metro Manila, respectively, are not included in the scope of this study.

The Meycauayan River has frequently flooded the Malabon, Navotas and Valenzuela (MANAVA) area. Therefore, the drainage plan of the MANAVA area is to be formulated under the condition that the floodwaters of the Meycauayan River is controlled completely by the construction of a dike on the left bank.

The Zapote River causes flooding to the low land area, but it is at present connected to a small river, the San Dionisio River. Since the drainage plan in the low land area could not be formulated without controlling the floodwaters of the Zapote River, the floodwaters of the Zapote River is planned to be drained directly into the Manila Bay.

Land Use Condition

The land use conditions at the year 2020 is employed. In the present study, the land use conditions at the year 2020 is the farthest that can be set. (Refer to Table 3.1-2.)

Runoff Discharge

The design discharge for this study was calculated on the basis of the land use conditions at the year 2020.

Safety Degree and Design Discharge

To prepare the Framework Plan, the following design return periods are adopted for the river and drainage systems.

- River System : 100-year return period

- Drainage System : 10-year return period

- Laguna Lakeshore Area: Recorded Maximum High Water Stage (40-year return period)

The above were determined from the review of the previous plan and studies, considering the importance of the metropolitan area with a high development potential. Flood control of rivers in the Philippines is mostly planned with a 100-year return period even though there is no definite standard. Drainage channels and facilities are planned to be constructed with a 10-year return period in the city of Manila and suburbs.

Hydraulic Boundary

The tide level of Manila Bay is set as follows in accordance with the results of the hydrological analysis.

(1) Manila Bay Tide

- River Flood Water Calculation : Mean Spring High Tide at 11.30 m

- Inland Water Drainage Calculation: 11.80 m, highest tide level on record

(2) Water Stage of Rivers

Adopted are the higher stage between the above Manila Bay tide level and the river water stage computed from non-uniform calculation with mean spring high tide at EL 11.30 m of Manila Bay.

5.2 Proposed Plans for River System

5.2.1 Features of Proposed River Plan

<u>Pasig-Marikina River</u>

(1) Basic Analysis for Selection of the Proposed Plan

To establish the flood control plan of the Pasig-Marikina River System, various plans or combination of plans were considered. Among them, the major components that can be independently studied are herein discussed ahead, as follows.

(a) Effect of Shortcut of the Pasig River

The possibility of a shortcut in the stretch of the meandering portion from Sta. 8+295 (downstream of San Juan River confluence point) to Sta. 11+295 (upstream of San Juan River confluence point) was investigated. The effect of water stage reduction by the construction of shortcut works cannot be expected much and this would require a huge construction cost and a number of house evacuation. Therefore, it has been concluded that the construction of a shortcut channel is not feasible.

(b) Improvement of San Juan River

The existing flow capacity of the San Juan River is less than 200 m^3/s and the runoff discharge of a 100-year return period is, on the other hand, estimated at 900 m^3/s. Several improvement plans for the San Juan River are studied.

The most recommendable improvement method is the plan which would increase the flow capacity by the construction of river wall and the excavation of the river channel, applying an approximate width equivalent to the present channel width to avoid a number of house evacuation.

(2) Proposed Plan

Several alternative plans were prepared in consideration of such basic factors as increment of flow capacity of the present Pasig River and utilization of the Laguna Lake as retarding basin.

After the comparative study from the economic and social aspects, proposed are the plans comprising river improvement works for the Pasig, Marikina and San Juan rivers, the MCGS construction works for diversion, and the Marikina Dam for discharge regulation.

The safety degree of the Pasig-Marikina River is set at 100-year return period by regulating the flood discharge with the Marikina Dam as well as confining the flood discharge in the river channel, and the safety degree of the proposed river improvement is 30-year return period. The remaining discharge of up to a 100-year return period is thus controlled by the Marikina Dam.

The main features of the proposed structures are as follows. The design discharge distribution is shown in Fig. 5.2-1.

(a) River Improvement

River Stretch	Design Discharge (m^3/s)	Length (m)	Width (m)	X-Section	Proposed Structures
River Mouth/ San Juan R. Confluence	1,150	8,735	250-80	Single (Rectangular/ Trapezoidal)	°Sheet Piles °Parapet Wall
San Juan R. Confluence/ Napindan R. Confluence	500	9,760	80-110	-ditto-	°Sheet Piles °Revetment °Parapet Wall
Napindan R. Confluence/ MCGS	500	5,580	110-100	Single (Trapezoidal)	°Revetment °River Wall
MCGS/Mangahan F. Confluence	500	1,210	100-130	-ditto-	°Revetment °River Wall
Mangahan F. Confluence/ Marikina Bridge	2,900	6,425	130-350	-ditto-	°Revetment °River Wall °Embankment

Marikina Bridge/Nangka R. Confluence	2,900	5,560	350-300	Compound	°Revetment °River Wall
Nangka R. Confluence/ Rodriguez Bridge	2,600	8,580	300-170	-ditto-	°Embankment
San Juan R.	900	10,653	40	Single (Rectangular/ Trapezoidal)	°Sheet Piles °Revetment °Parapet Wall

(b) Marikina Control Gate Structure (MCGS)

The MCGS as shown in Fig. 5.2-2 is to be constructed at just downstream of the confluence with the Mangahan Floodway to divert the discharge of 2,400 m^3/s into the floodway.

Location : Downstream of confluence with Mangahan Floodway (Sta. 5+425)

Type of Gate : Roller Gated Weir

Height : 15 m

(c) Marikina Dam (see Fig. 5.2-3)

Dam construction is possible only in the upper reach of the Marikina River. In this study, the natural discharge regulation method without artificial operation by gate is considered to avoid a man-made flood. The dam will be known as the Marikina Dam as previously proposed.

Location : Montalban Gorge (100 m downstream of the existing Wawa Dam)

Type of Dam : Concrete Gravity Type

Height : 70 m

Malabon-Tullahan River

Since the basin of the Malabon-Tullahan River has been well developed, it is practically difficult to construct flood regulation facilities such as reservoir, retarding basin, etc., in the upper reaches.

To flow out the design discharge of the river safely to the sea in the downstream area, the improvement of the existing river channel is proposed as the optimum plan. The design discharge distribution is presented in Fig. 5.2-1.

The features of the proposed river improvement works are summarized as follows, and the layout of the proposed stretches of the river is shown in Fig. 5.2-4.

River Stretch	Design Discharge (m^3/s)	Length (m)	Width (m)	X-Section	Proposed Structures
Malabon River	570-520	5,430	100-90	Single (Trapezoidal)	°Revetment °Parapet Wall °Embankment
Tullahan River	480-240	20,500	90-20	-ditto-	°Revetment °Parapet Wall °Embankment

Buli-Baho-Mahaba River

There are three rivers that flow into the Laguna Lake through the drainage channel provided along the left side of the Mangahan Floodway to the lake; namely, the Buli River, the Baho River, and the Mahaba River. The flow capacity of their river channels is extremely small, and the channels run through the densely populated urban area.

The channel improvement by expanding the existing channel width and excavation/dredging of the channel bed is the most and only viable measure for the upper and middle reaches. In this case, a shortcut from the Baho River to the Buli River is employed because of the apparently lesser cost and house evacuation than the improvement works for the Baho River which runs through the densely populated areas.

Considering the technical point of view, it is proposed that a backwater dike to connect with the Laguna Lake is constructed in the lower reaches. Two alternative plans, i.e., drainage into the Mangahan Floodway and drainage into the Laguna Lake, were also studied with the construction of backwater dike. Although both plans show only a little difference in their construction cost and the number of house evacuation, the measure of drainage into the Laguna Lake is considered to be more applicable for the reason that the measure of drainage into the Mangahan Floodway may cause considerable scouring at the confluence points between the rivers and the floodway. (Refer to Fig. 5.2-5.)

The features of the proposed river improvement works are summarized as follows, and the layout of the proposed stretches is shown in Fig. 5.2-6.

River Stretch	Design Discharge (m^3/s)	Length (m)	Width (m)	X-Section	Proposed Structures
Mahaba River	190	5,000	50-25	Single (Trapezoidal)	°Embankment
Baho River	335-280	7,450	50-40	-ditto-	-ditto-
Buli River (incl. tributaries)	330-80	19,900	50-10	-ditto-	-ditto-
Mangahan Diversion	570-340	3,800	90-60	-ditto-	-ditto-

South Parañaque-Las Piñas River

The upstream of the rivers included in this area is already urbanized, especially recently, and flood control by reservoir is not recommendable. The optimum way is to drain the runoff discharge from the upstream hilly land or mountain area into the Manila Bay directly by channel improvement. (Refer to Figs. 5.2-6 and 5.2-7.)

The features of the proposed plan are as follows, and the layout of the proposed stretches is shown in Fig. 5.2-7.

River Stretch	Design Discharge (m^3/s)	Length (m)	Width (m)	X-Section	Proposed Structures
Las Piñas River	250-220	6,395	50-30	Single (Trapezoidal)	°Revetment °Parapet Wall °Embankment
South Parañaque River (incl. Dongalo River)	630-200	6,500	70-30	-ditto-	-ditto-

Laguna Lake

The level of EL 12.5 m corresponding to the average annual maximum water level which is the lowest level for land use in accordance with a presidential instruction is set as the allowable design lake water levels.

The Laguna lakewater is now discharged into the Manila Bay through the Napindan Channel, the Mangahan Floodway and the Pasig River. Thus, the lakewater stage is deeply related to the flow capacity of these channels. Lowering the lake water stage to EL 12.5 m by the Mangahan Floodway and the improvement of the Pasig River and the Napindan Channel has technical limitations due to the tidal backwater and the discharge of the Marikina and San Juan rivers. Furthermore, the improvement of the Pasig and the Napindan will require a huge construction cost.

On the contrary, the Parañaque Spillway with a channel width of 60 m will enable the lakewater stage to fall down to EL 12.5 m with the cost and evacuated houses lesser than the measure of Pasig and Napindan channel improvement. Thus, this measure may be concluded as more practicable.

The structural features are as follows.

Proposed Structure	Design Discharge (m^3/s)	Length (m)	Width (m)	Dimension
Pasig River Improvement	1,150-500	18,500	250-80	River Mouth/Napindan River Confluence
Napindan Channel Improvement	400 (max)	5,242	100	Channel Bottom: 80.0 in width
Lakeshore Dike	-	10,700	9.1	Dike Top Elevation: EL 14.20 m incl. 1.7 m freeboard
Parañaque Spillway	500 (max)	9,200	150-80	Channel Bottom: 60 m in width

5.2.2 Features of Proposed Drainage Plan

The areas which will need a drainage system have been identified on the basis of the past floods and the topography. These areas are grouped into nine drainage areas and the proposed drainage facilities are described hereinafter. The layout of drainage facilities for each area is as presented in Fig. 5.2-8.

Manila and Suburbs

Manila and suburbs is a low land along Manila Bay. This area is divided into the North Manila and Suburbs and the South Manila and Suburbs. Both areas are provided with drainage channels and pump stations. However, to protect this area from a 10-year return period flood, further improvement works such as extension/construction of pump stations, lowering of the bed of esteros, and installation of drainage mains have been planned.

The features of the proposed drainage facilities are as follows.

Proposed Structure	Quantity	Dimension
(1) North Manila (Drainage Area: 2,858 ha)		
New Pump Station	3 sites	15.5 cums in total
Extension of Existing Pump Station	2 sites	9.2 cums in total
Gate	1 site	15 tons in total

Channel Improvement	6,850 m	17-7 m in width
Closed Channel Construction	5,750 m	3.8-2.5 m in width

(2) South Manila (Drainage Area: 4,314 ha)

New Pump Station	1 site	5.3 cums in total
Extension of Existing Pump Station	5 sites	18.3 cums in total
Gate	2 sites	25 tons in total
Channel Improvement	7,750 m	30-5 m in width

Malabon-Navotas

Most of this area has a very low-lying and flat topography located along the Manila Bay. Therefore, inundation is attributed to high tide rather than river flood. The proposed measures in this drainage area are, basically, the construction of ring dikes to protect areas from high tide, pump stations to drain inland water, and drainage channels to collect inland water.

Regarding the location of ring dikes, those proposed in the Feasibility Study were applied to the Framework Plan. Four pumping stations along the proposed dikes cover all the low areas north of the Malabon-Tullahan River, so that the integration of pumping stations will minimize cost and the existing rivers/creeks in the area are used as main drainage channels. The features of the proposed drainage facilities for this drainage area are as follows.

Proposed Structure	Quantity	Dimension
(Drainage Area: 2,492 ha)		
Ring Dike (Reinforcement of existing dike)	22,000 m	
Pump Station	8 sites	76.1 cums in total
Gate	15 sites	240 tons in total
Channel Improvement	5,100 m	12 m in width
Open Channel Construction	5,600 m	12-23 m in width

Closed Channel Construction	800 m	3 m in width x 3 units
Navotas Navigation Lock	1 site	20 m in width, 180 m in length

East of Mangahan

This area which is situated just east of the Mangahan Floodway, is seriously affected whenever the Laguna lake stage becomes high as witnessed in 1986 and 1988.

In addition to the lakeshore dike to protect this area from inundation due to the high lake stage, the construction of pump stations and the construction/improvement of drainage channels to drain the inland water are proposed, following the drainage plan to be implemented. For some of the pumping stations, regulation ponds are proposed in the areas with available open space. The features of the drainage facilities are as follows:

Proposed Structure	Quantity	Dimension
(Drainage Area: 876 ha)		
Pump Station	4 sites	31.1 cums in total
Gate	4 sites	90 tons in total
Channel Improvement	1,100 m	20-75 m in width
Open Channel Construction	7,300 m	20-7 m in width
Regulation Pond	2 sites	60,300 m^3 in storage

West of Mangahan

The West of Mangahan is an extensive low-lying area bordering on the Marikina River, the Mangahan Floodway and the Laguna Lake. In 1986 and 1988, most of this area was inundated for two or three months due to the high Laguna lake stage. For the same reason mentioned in East of

Mangahan, mechanical drainage method is proposed with the construction of the lakeshore dike. Regulation ponds will also be employed using the open space along the lakeshore dike.

Proposed Structure	Quantity	Dimension
(Drainage Area: 3,814 ha)		
Pump Station	5 sites	147.6 cums in total
Gate	10 sites	350 tons in total
Channel Improvement	34,100 m	40-10 m in width
Open Channel Construction	11,000 m	20-7 m in width
Closed Channel Construction	1,450 m	3.5 m in width x 3 units
Regulation Pond	4 sites	775,500 m^3 in storage

San Juan

The San Juan River flows down in a hilly land, but along its course lie low areas where inland water inundation may occur even after river improvement works of the San Juan River. To protect these areas from flooding, the construction of new pump stations and floodgates are proposed for some of the areas and also, closed drainage channels will be installed in such areas.

For the three tributaries with low bank elevations at the confluence with the San Juan River that cannot discharge inland water, backwater dikes are proposed to drain floodwaters into the San Juan River.

Proposed Structure	Quantity	Dimension
(Drainage Area: 1,260 ha)		
Pump Station	9 sites	52.7 cums in total
Gate	13 sites	128 tons in total
Channel Improvement	1,300 m	8.4 m in width

Closed Channel Construction	12,300 m	5.7-2.2 m in width
Backwater Dike	3,400 m	3.6-2.0 m in height

Mandaluyong-Pasig

Low land which suffers flooding from the river and by inland water extends along both sides of the Marikina River between the Mangahan Floodway and the Napindan HCS and along the right side of the Pasig River between EDSA and the junction with the San Juan River. The areas located along the remaining reaches are high and no flooding is experienced, therefore, the objective area for the drainage system plan is limited to the areas that include the low land mentioned above. Pump stations are proposed in the very low area in Pasig, together with the construction/improvement of drainage channels, while in the remaining areas, construction/improvement of drainage channels is proposed.

Proposed Structure	Quantity	Dimension
(Drainage Area: 1,525 ha)		
Pump Station	3 sites	23.0 cums in total
Gate	3 sites	47 tons in total
Channel Improvement	2,500 m	11.3-8.2 m in width
Closed Channel Construction	8,800 m	4.5-2.9 m in width

Marikina

There are lowlands along the Marikina River from the junction with the Nangka River to the Mangahan Floodway. The existing residential areas suffered from serious flood damage especially in the 1988 flood and, moreover, the present agricultural land in the flood prone area is planned to be changed into an urban area. The proposed facilities are floodgate and drainage channel in one subdrainage area, while only drainage channels are planned in other areas since gravity drainage can be attained without gates.

Proposed Structure	Quantity	Dimension
(Drainage Area: 1,168 ha)		
Gate	1 site	10 tons in total
Open Channel Construction	1,000 m	15 m in width
Closed Channel Construction	2,600 m	9 m in width

Parañaque-Las Piñas

Flooding in this area is caused by floodwaters from rivers such as South Parañaque, Las Piñas and Zapote, as well as inland water. In addition, the water discharged from the Tripa de Gallina Pumping Station worsens the flood situation along the Parañaque River. The improvement works on such rivers as the above divide the area into four subdrainage areas.

There exist three outfalls which connect the Parañaque River and the Manila Bay, aiming to drain flood water including the Tripa de Gallina Pumping Station. The drainage capacity of the existing outfalls is limited, therefore, a new cut-off channel from the Tripa de Gallina Pump Station to the Manila Bay is proposed to be constructed.

Without inflow from the Tripa de Gallina subdrainage areas, the Parañaque River can store the inland water when initial water level is lowered to the mean sea level by control gates located at the junction of the South Parañaque River and the inlet of the outfalls. In other subdrainage areas, pump drainage is proposed, except for areas which can drain inland water by gravity flow.

Proposed Structure	Quantity	Dimension
(Drainage Area: 1,543 ha)		
Pump Station	2 sites	19.8 cums in total
Gate	8 sites	195 tons in total
Channel Improvement	4,800 m	15-8.7 m in width
Open Channel Construction	150 m	20 m in width

Cut-off Channel	500 m	30 m in width

Valenzuela

Valenzuela is a low-lying area which suffers inundation by high water from the Meycauayan River, as well as high tide. The proposed drainage method is the installation of pump stations and the improvement of existing creeks, as well as the construction of ring dike along the Meycauayan River and small creeks.

Proposed Structure	Quantity	Dimension
(Drainage Area: 1,842 ha)		
Pump Station	3 sites	10.9 cums in total
Gate	1 site	15 tons in total
Ring Dike (Reinforcement of existing dike)	8,000 m	1.0 m heightening
Channel Improvement	12,900 m	30-10 m in width
Open Channel Construction	500 m	3 m in width

5.3 Construction Cost

The construction cost of the Framework Plan is estimated at 21,860 million pesos at the price level of October 1988, excluding price contingency; 8,205 million pesos for the river improvement, 4,000 million pesos for the Parañaque Spillway, and 9,655 million pesos for the drainage improvement works. The breakdown of cost for each river or drainage system is in Table 5.3-1. The location of the Framework Plan is shown in Fig. 5.2-9.

CHAPTER 6. MASTER PLAN

6.1 Premises and Conditions for the Study

The premises and conditions for the Master Plan Study are the same as those of the Framework Plan Study, except the following.

Target Completion Year

The year 2020 is set as the target completion year, considering the land use conditions which are closely related to runoff and vulnerability to flood loss. (Refer to Table 3.1-2.)

Premises for Structural Application

The Framework Plan was formulated without considering financial restrictions. On the contrary, the Master Plan is to formulate the flood control and drainage project that could be realized by the year 2020 within the financial availability up to that year. Since the Parañaque Spillway which will require a huge amount of funds is considered to be practically difficult to realize within the year 2020, the spillway is excluded in the formulation of the Master Plan.

Discharge

(1) Runoff Discharge

The design discharge for this study was calculated on the basis of land use conditions at the year 2020.

(2) Diversion Discharge through Mangahan Floodway

The maximum diversion discharge of Mangahan Floodway is set at 2,400 m^3/s.

Hydraulic Boundary

The tide level of Manila Bay and the water stage of the Laguna Lake were set as follows in accordance with the results of the hydrological analysis.

(1) River Water Stage Calculation

- Manila Bay Tide : Mean Spring High Tide at 11.30 m.

- Laguna Lake Stage : 12.50 m, to avoid double accounting of damage due to inland water inundation and flood water inundation of river.

(2) Inland Water Drainage Calculation

- Manila Bay Tide : 11.80 m, highest tide level on record.

- Water Stage of River : Adopted are the higher stage between the above Manila Bay tide level and the river water stage computed from non-uniform calculation with mean spring high tide at 11.30 m of Manila Bay.

- Laguna Lake Stage : 13.80 m, obtained from hydrological analysis, to reduce the recorded maximum lake stage of 14.03 in 1972, considering the flood diversion through Mangahan Floodway to the lake and the reverse flow capacity of the floodway, together with the flow-down into the Pasig River through the Napindan Channel, to lower the lakewater level.

6.2 Alternative Study Cases

For the flood control of rivers and inland water drainage, the study on the Master Plan was done under the following alternative cases.

Flood Control of Rivers

For each of the objective rivers, the improvement scale of structures and facilities was considered in five alternative cases; namely, 10, 20, 30, 50 and 100-year return periods.

Drainage of Inland Water

The improvement scale of facilities for the drainage of inland water was studied in four alternative cases of 2, 3, 5 and 10-year return periods for the 9 drainage areas mentioned before.

6.3 Justification of the Alternative Cases

Flooding Calculation

Flooding inundation by river water with return periods of 2, 5, 10, 20, 30, 50 and 100-year was calculated under the existing condition of the respective rivers. The obtained inundation water stage for these seven return periods of flood are shown in Table 6.3-1.

Inundation Calculation

The inland water inundation condition was calculated in consideration of the following scale of structures and facilities.

- Manila and Suburbs	:	Existing condition and 10-year return period
- Other Areas	:	Existing condition, and 2, 3, 5 and 10-year return periods

By adopting the above scale of structures and facilities, the following return periods of flood were considered in all drainage areas in Metro Manila: 2, 3, 5, 10, 30, 50 and 100-year return period flood. The estimated inundation water stages are as shown in Table 6.3-2.

Economic Efficiency of the Alternative Study Cases

As discussed in Section 6.2, set up are five study cases for four river systems and four cases for nine drainage areas, or a total of 56 alternative study cases. Benefit/Cost ratio was verified to confirm the economic efficiency for each study case on the following assumptions.

- Construction period is five years at equal annual disbursements;

- Economic construction cost is 90% of the estimated cost;

- Annual OMR cost is as estimated;

- Project life is 40 years after construction; and

- Discount rate is 15% per annum.

Details of the project cost are described in Subsection 6.4.5, and the annual average benefit was estimated as discussed in Subsection 6.4.6. The estimated benefit/cost ratios are presented in Table 6.3-3.

6.4 Formulation of the Master Plan

6.4.1 Selection of Optimum Plan

The optimum structural and non-structural measures for the Master Plan were selected through the following studies.

Optimum Structural Measure

The optimum structural measures are proposed in consideration of the following conditions.

(1) Grouping of River Courses/Drainage Areas

The Framework Plan has been formulated to protect Metro Manila from flooding/inundation of 100-year and 10-year return periods for the river course and drainage area, respectively. However, it is financially infeasible to put this plan into implementation. In formulating the Master Plan, therefore, financial capacity is one of the planning criteria. This can be attained by applying a lower degree of safety from flooding or varying the design return period according to the river course/drainage area.

The safety degree of applicable structures and facilities for flood control is determined depending on the economic viability and social significance of each river course/drainage area. However, there are four river courses and nine drainage areas and some of them show a very similar economic viability and social significance. Determination of the safety degree for each river course/drainage area is so difficult that it is proposed to classify them into several groups as follows.

(a) River System

Economic viability shows only a little difference among all the rivers, although economic viability for the Pasig-Marikina River is relatively higher than those of the other rivers. Considering that the Pasig-Marikina River runs through the heart of Metro Manila which is the political, economic and social center of the Philippines, the degree of safety for this river system is likewise set higher than the other rivers. Thus, the objective river systems were classified into the following two groups.

Group A (Most Important)	:	Pasig-Marikina River (including San Juan River)
Group B (Important)	:	Buli-Baho-Mahaba River; Malabon-Tullahan River; and South Parañaque-Las Piñas River

(b) Drainage System

In Manila and Suburbs, the drainage facilities are already set with a certain degree of safety, and will be improved under the 14th OECF Loan. In other areas, however, no countermeasures are provided, or that the facilities are inappropriate. These other areas will be classified into two groups, one group with the B/C ratio of more than 1.7 and the other with the B/C ratio of less than 1.7 (refer to Table 6.3-3). Thus, drainage areas will be classified into the following three groups.

Group A (Most Important)	:	Manila and Suburbs
Group B (More Important)	:	West of Mangahan; East of Mangahan; and Malabon-Navotas
Group C (Important)	:	San Juan; Mandaluyong-Pasig; Parañaque-Las Piñas; and Valenzuela

(2) Alternative Combinations and Selection of Optimum Plan

Based on the above grouping of drainage area, alternative combinations are set up in terms of the project scale expressed in flood return period on the following considerations.

- To rank the groups according to their economic viability and social significance; and

- To place a higher safety degree on the higher ranked groups.

Alternative combinations are thus suggested below with the maximum safety degree of 100-year and 10-year return periods for the river course and drainage area, respectively.

Alternative	River		Drainage		
	Group A	Group B	Group A	Group B	Group C
Case 1	1/100	1/50	1/10	1/10	1/5
Case 2	1/100	1/30	Existing	1/5	1/3
Case 3	1/30*	1/30	Existing	1/5	1/3
Case 4	1/30*	1/20	Existing	1/3	1/2
Case 5	1/100	-	1/10	1/10	-
Case 6	1/30*	-	Existing	1/5	-

[Note] * With respect to the flood control of the Pasig-Marikina River, the 100-year flood is controlled with a dam and river channel improvement works. The most economical allocation between them is a 30-year return period for the river channel. Therefore, the maximum safety degree without a dam is considered at a 30-year return period.

The total construction cost required for the above alternative cases are as follows. The breakdown of cost is in Table 6.4-1.

Case 1	:	17,009 million pesos
Case 2	:	13,523 " "
Case 3	:	12,884 " "
Case 4	:	12,015 " "
Case 5	:	10,751 " "
Case 6	:	7,250 " "

Case 2 is selected as the optimum plan on the ground that the required project cost corresponds to the accumulated amount of public investment on the flood control and drainage sector by the year 2020 that could be attained by the potential economic growth rate of 4% in the future Philippine economy. The location of the optimumn plan is shown in Fig. 6.4-1.

Optimum Non-Structural Measure

(1) Publication of Flood Risk Map and Introduction of Flood Proofing

The flood risk map is proposed to demarcate the present probable inundation areas caused either by the river channel overflow or by the local storm rainfall. River channel overflow will have a long recurrence period, but once it occurs, it will bring about severe damage in a wide area and may cause heavy casualties. In this connection, the flood risk map for the overflow of the Pasig-Marikina River was estimated, as shown in Fig. 6.4-2, assuming a 100-year return period flood which corresponds to the proposed design flood level for the river channel improvement. As for the other rivers, however, except for the Pasig-Marikina River, the inundation phenomena is not so clear for the ground level information. Therefore, the flood risk map of Buli-Baho-Mahaba River, Malabon-Tullahan River and South Parañaque-Las Piñas River could not be prepared in this study.

On the other hand, the local storm rainfall will have a smaller inundation area with a shorter recurrence period. The estimation of the flood risk map for the local storm rainfall will also require the subtle ground level information and could not be made during this study stage due to the insufficient available information on ground level.

The flood risk map should be published for the information of people dwelling within the probable inundation area, and flood proofing measures such as raising the floor elevation of houses/buildings should be introduced. Through these non-structural measures, the flood damage potential will be substantially reduced.

(2) Establishment of Flood Warning System and Enforcement of Emergency Activity

The flood warning system is proposed for the flood runoff discharges of the Pasig-Marikina River where flood forecasting will be available subject to the flood lag time of about two hours. The NCR head office will carry out the flood forecasting through the telemetry facilities of the EFCOS Project, and instruct the six NCR engineering district offices to take the necessary operation of the existing 10 pumping stations and four floodgates. The results of the flood forecasting will also be forwarded to the Metro Manila Disaster Coordinating Council (MMDCC) so as to disseminate the flood warning and enforce the proper emergency activities.

6.4.2 Features of Proposed Plan

River Flood Control Works

The proposed structures and facilities are fundamentally the same as the those proposed in the Framework Plan. The only difference is the return period, i.e., 100-year for the Pasig-Marikina River and 30-year for the other rivers. The discharge distribution for river flood control works is as shown in Fig. 6.4-3, while the plan for the respective rivers is explained as follows (refer to Fig. 6.4-4).

(1) Pasig-Marikina River

The proposed structures of the Master Plan which are prepared with a 100-year return period are the same as those of the Framework Plan. The only difference is the flood warning system which is added as a non-structural measure in the master plan.

(a) River Improvement

River Stretch	Design Discharge (m^3/s)	Length (m)	Width (m)	X-Section	Proposed Structures
River Mouth/ San Juan R. Confluence	1,150	8,735	250-80	Single (Rectangular/ Trapezoidal)	°Sheet Piles °Parapet Wall
San Juan R. Confluence Napindan R. Confluence	500	9,760	80-110	- ditto -	°Sheet Piles °Revetment °Parapet Wall
Napindan R. Confluence/ MCGS	500	5,580	110-100	Single (Trapezoidal)	°Revetment °River Wall
MCGS/Mangahan F. Confluence	500	1,210	100-130	- ditto -	°Revetment °River Wall
Mangahan F. Confluence/ Marikina Bridge	2,900	6,425	130-150	- ditto -	°Revetment °River Wall °Embankment
Marikina Bridge/Nangka R. Confluence	2,900	5,560	350-300	Compound	°Revetment °River Wall
Nangka R. Confluence/ Rodriguez Bridge	2,600	8,580	300-170	- ditto -	°Embankment
San Juan R.	900	10,653	40	Single (Rectangular/ Trapezoidal)	°Sheet Piles °Revetment °Parapet Wall

(b) Marikina Control Gate Structure (MCGS)

Location	:	Downstream of Rosario Weir (Sta. 5+425)
Type of Gate	:	Roller Gated Weir
Height	:	15 m

(c) Marikina Dam

Location	:	Montalban Gorge (100 m downstream of the existing Wawa Dam)
Type of Dam	:	Concrete Gravity Type
Height	:	70 m
Discharge Regulation	:	Natural discharge regulation without operation by gate

(d) Flood Warning System

The flood warning center will be placed at the NCR head office. The following equipment are provisionally proposed as the component of the flood warning system.

Patrol Car (5 units)	:	Each car will be 4WD type with radio communication equipment.
Radio Equipment for Voice Communication	:	The communication network will be among the flood warning center, the office of MMDCC, the six NCR engineering district offices, the 10 pumping stations and four flood gates.

(2) Malabon-Tullahan River

The proposed river improvement works consist of the same structural component as those of the Framework Plan. The only difference is the return period which adopted th 30-year return period of the Master Plan.

River Stretch	Design Discharge (m^3/s)	Length (m)	Width (m)	X-Section	Proposed Structures
Malabon River	500-450	5,430	80-70	Single (Trapezoidal)	°Revetment °Parapet Wall °Embankment
Tullahan River	420-210	20,500	80-15	-ditto-	°Revetment °Parapet Wall °Embankment

(3) Buli-Baho-Mahaba River

The proposed river improvement works consist of the same structural component as those of the Framework Plan. The only difference is the return period which adopted the 30-year in the Master Plan.

River Stretch	Design Discharge (m^3/s)	Length (m)	Width (m)	X-Section	Proposed Structures
Mahaba River	160	5,000	45-20	Single (Trapezoidal)	°Embankment
Baho River	275-230	7,450	45-35	-ditto-	-ditto-
Buli River (including Tributaries)	270-50	19,900	45-5	-ditto-	-ditto-
Mangahan Diversion	470-280	3,800	80-55	-ditto-	-ditto-

(4) South Parañaque-Las Piñas River

The proposed river improvement works consist of the same structural component as those of the Framework Plan. The only difference is the return period which adopted the 30-year in the Master Plan.

River Stretch	Design Discharge (m^3/s)	Length (m)	Width (m)	X-Section	Proposed Structures
Las Piñas River	210-180	6,395	45-25	Single (Trapezoidal)	°Revetment °Parapet Wall °Embankment
South Parañaque River (incl. Dongalo River)	520-170	6,500	60-25	-ditto-	-ditto-

Drainage Improvement Works

Drainage facilities are proposed for eight drainage areas out of the nine areas defined before. Excluded is the Manila and Suburbs area which will have facilities with the safety degree of more than a 5-year return period after completion of the on-going project.

The proposed facilities are of the same type as those in the Framework Plan, with a different degree of safety in most of the drainage areas. As the layout of proposed drainage facilities, only that for Valenzuela is indicated in Fig. 6.4-5 since the mechanical drainage proposed in the Framework Plan is changed to drainage by gate control. The layout of facilities for other drainage areas is the same as those shown in Fig. 5.2-8. The features of the proposed facilities are tabulated hereunder, together with the design safety degree for drainage facilities. Any deviation from the Framework Plan is also explained.

(1) Malabon-Navotas

Design Safety Degree: 5-year Return Period

Proposed Structure	Quantity	Dimension
Ring Dike (Reinforcement of existing dike)	22,000	
Pump Station	8 sites	62.1 cums in total
Gate	15 sites	225 tons in total

Channel Improvement	5,100 m	10-20 m in width
Open Channel Construction	5,600 m	10.1-5.3 m in width
Closed Channel Construction	800 m	2.7 m in width x 3 units
Navotas Navigation Lock	1 site	20 m in width, 180 m in length

The Dagat-Dagatan area with an existing drainage system is excluded from the Master Plan since the existing system has the capacity of more than 5-year return period.

(2) East of Mangahan

Design Safety Degree: 5-year Return Period

Proposed Structure	Quantity	Dimension
Lakeshore Dike	1,800 m	Top of Dike: EL 15.5 m
Pump Station	4 sites	27.0 cums in total
Gate	4 sites	84 tons in total
Channel Improvement	1,100 m	15-10 m in width
Open Channel Construction	7,300 m	15-5 m in width
Regulating Pond	2 sites	51,000 m^3 in sotrage

(3) West of Mangahan

Design Safety Degree: 5-year Return Period

Proposed Structure	Quantity	Dimension
Lakeshore Dike	8,900 m	Top of Dike: EL 15.5 m
Pump Station	5 sites	129.0 cums in total
Gate	10 sites	342 tons in total
Channel Improvement	34,100 m	35-5 m in width
Open Channel Construction	11,000 m	15-5 m in width

Closed Channel Construction	1,450 m	3 m in width x 3 units
Regulating Pond	4 sites	642,000 m^3 in storage

(4) San Juan

Design Safety Degree: 3-year Return Period

Proposed Structure	Quantity	Dimension
Pump Station	9 sites	31.0 cums in total
Gate	13 sites	102.5 tons in total
Channel Improvement	1,300 m	7.7 m in width
Closed Channel Construction	12,300 m	5.2-2.0 m in width
Backwater Dike	3,400 m	3.6-2.0 m in height

(5) Mandaluyong-Pasig

Design Safety Degree: 3-year Return Period

Proposed Structure	Quantity	Dimension
Pump Station	3 sites	14.5 cums in total
Gate	3 sites	40.0 tons in total
Channel Improvement	2,500 m	10.5-7.9 m in width
Closed Channel Construction	8,800 m	4.2-2.7 m in width

(6) Marikina

Design Safety Degree: 3-year Return Period

Proposed Structure	Quantity	Dimension
Gate	1 site	7 tons in total
Open Channel Construction	1,000 m	12 m in width
Closed Channel Construction	2,600 m	7 m in width

(7) Parañaque-Las Piñas

Design Safety Degree: 3-year Return Period

Proposed Structure	Quantity	Dimension
Pump Station	2 sites	12.5 cums in total
Gate	8 sites	175 tons in total
Channel Improvement	4,800 m	13.9-8.0 m in width
Open Channel Construction	150 m	15 m in width
Cut-off Channel	500 m	25 m in width, open channel type

The safety degree is 10-year return period for the cutoff channel which drains the floodwater of the Tripa de Gallina P.S. drainage district in Manila and Suburbs to the Manila Bay.

(8) Valenzuela

Gate control is proposed, since the inundation depth is lower than the allowable depth everywhere for the flood of a 3-year return period due to the storage capacity of rivers and fishponds and the flat topography.

Design Safety Degree: 3-year Return Period

Proposed Structure	Quantity	Dimension
Gate	1 site	10 tons in total
Ring Dike (Reinforcement of existing Dike)	8,000 m	1.0 m raising in ht.
Channel Improvement	12,900 m	12.1-6.3 m in width
Open Channel Construction	500 m	2 m in width

6.4.3 Implementation Schedule

The implementation schedule for the Master Plan spans a long period of 30 years from 1991 to 2020. Due to the difficulty of scheduling precisely for this long period, the construction works are proposed to be implemented in three phases, and the order of construction is determined on the following criteria.

- Works with a high economic viability should be constructed prior to the others.
- Priority should be placed on the areas where there would be a considerable socioeconomic problem in case of flooding.
- Consideration should be given to the equal distribution of annual construction cost.

Based on the above, the order of construction thus selected are as follows. Detailed explanation for Phase I is made in Section 6.1. The implementation schedule is presented in Fig. 6.4-6.

Phase	Drainage Area	River System	Total Construction Cost (million ₱)
Phase I (1991-2000)	° East and West of Mangahan ° Malabon and Navotas (First Stage)	° Pasig-Marikina downstream of Mangahan	4,677
Phase II (2001-2010)	° San Juan ° Mandaluyong and Pasig ° Marikina ° Parañaque and Las Piñas ° Valenzuela ° Malabon and Navotas (remaining area)	° Pasig-Marikina upstream of Mangahan	4,312
Phase III (2011-2020)	- None -	° Baho, Buli and Mahaba ° Malabon and Tullahan ° South Parañaque and Las Piñas ° San Juan ° Marikina Dam	4,534

As for the Pasig-Marikina upstream of the Mangahan Floodway and the Marikina Dam, it is technically advisable to implement river improvement works because these can control floodwaters from a wider drainage area than the dam.

6.4.4 Proposed Organizational Setup

The flood control and drainage projects nationwide including the Metro Manila area are presently executed by the Department of Public Works and Highways (DPWH), under Executive Order No. 124 of January 1987. The minor drainage laterals in Metro Manila are maintained by the local governments such as the Metropolitan Manila Commission (MMC) and city/municipality.

Aside from the DPWH, other concerned agencies are also involved in the planning of flood control and drainage projects in Metro Manila such as the National Economic and Development Authority (NEDA) and the Laguna Lake Development Authority (LLDA).

In view of the above situation there are many agencies related to the flood control and drainage program, and it is recommended that an integrated institution, like a Committee for decision making, be created to ensure the effective and smooth implementation of proposed projects (refer to Table 6.4-2). A Technical Working Group (TWG) will be established to serve as the technical subagency of the Committee (refer to Table 6.4-3). The PAGASA and the Office of Civil Defense (OCD) will also be joined in the TWG for the purpose of flood forecasting and flood defense.

The practical implementation for the proposed project will be undertaken by DPWH and local governments according to the existing activities on flood control and drainage. The proposed organizational diagram of flood control and drainage projects is shown in Fig. 6.4-7.

The planning, construction and operation and maintenance of the proposed flood control and drainage facilities such as rivers, esteros, drainage mains/outfalls and major drainage laterals will be under the jurisdiction of the DPWH from the existing function, while the maintenance of minor drainage laterals and street gutters connected to local government structures and/or secondary/tertiary roads would be tasked to local governments such as the MMC and the city/municipality concerned. (Refer to Table 6.4-4.)

The implementation of flood control and drainage projects in Metro Manila is presently undertaken by the DPWH through the NCR and the PMOs such as the PMO for Flood Control and Dredging Projects and the PMO for Metro Manila Infrastructure Utilities and Engineering (MMINUTE).

The PMO for Flood Control and Dredging Projects will undertake the planning, design and construction of major proposed projects in view of the project scale. The DPWH-NCR will be able to execute the planning, design, and construction of ordinary flood control and drainage projects, as well as the operation and maintenance (O&M) of proposed projects from the present function. The PMO for MMINUTE can execute the provision of technical assistance to the local governments as it presently undertakes.

Furthermore, it is recommended that a Flood Control and Drainage Office be established in DPWH-NCR to execute the integrated flood control and drainage projects, after the merger and acquisition of the Flood Control and Drainage Division, the Pumping Stations and Floodgates Division, and a part of the flood control and drainage activities of the Planning and Design Division and the Materials Quality Control and Hydrology Division. The proposed office may allot the functions concerned to the Planning and Design Division, the Construction Division and the Operation and Maintenance Division (refer to Fig. 6.4-8).

Street gutters connected with national roads should be maintained by the Maintenance Division of DPWH-NCR, which is presently responsible for the maintenance of roads and bridges, because street gutters are parts of the road.

6.4.5 Project Cost

Project Cost consists of the construction cost and the operation, maintenance and replacement cost.

Construction Cost

(1) Estimation Condition

(a) Unit Cost

The unit construction cost was determined on the basis of the actual price of equipment, materials and labor as of October 1988, with reference to the unit costs adopted in similar projects in the Philippines. As for earthworks, two kinds of unit cost were considered in accordance with the access condition and the transportation distance to the construction sites.

The details for the units costs for major works are as indicated in Table 6.4-4.

(b) Cost for Preparatory Works and Compensation

For civil works except the revetment work, since the percentage of the preparatory works in the cost of civil works is commonly placed at 15 to 20%, 20% was adopted in this project considering that the miscellaneous works are included in the preparatory works.

Revetment works which is to be done mainly by manual labor, will require underwater work, and the preparatory works for dewatering is deemed different in accordance with the water depth of the construction sites. Therefore, the rate of the cost for the preparatory work where the revetment work is included, was classified into three groups of 30, 50 and 80% in accordance with the water depth. The detailed breakdown is shown in Table 5.6-6.

(c) Breakdown of Construction Cost

Construction cost consists of Cost for Major Civil Works, Cost for Preparatory Works and Compensation, Cost for Engineering Services and Administration, and Contingencies. The rate of the cost of the respective works involved in the total cost was considered as shown in Table 6.4-5.

(2) Estimated Construction Cost

The construction cost of the Master Plan is estimated at 13,523 million pesos at the price level of October 1988, excluding price contingency. This cost consists of 7,390 million pesos for the river improvement works and 6,133 million pesos for the drainage improvement works. The breakdown of cost is in Table 6.4-6.

Operation, Maintenance and Replacement Cost

(1) Estimation Condition

Operation and Maintenance Cost is estimated on the basis of the rate involved in the direct construction cost which consists of the cost for major civil works and the cost for preparatory works. The rates of operation cost and maintenance cost will depend on the employed structures and facilities, as follows.

- Common Civil Works : 0.3%
- Steel Gate : 1.0%
- Pump : 1.5%

As for the replacement cost, the durable life of structures and facilities is set as follows.

- Common Civil Works : 40 years
- Steel Gate : 30 years
- Pump : 15 years

(2) Estimated Operation, Maintenance and Replacement Cost

The annual operation, maintenance and replacement cost for the proposed plan is estimated as shown in Table 6.4-7.

6.4.6 Annual Average Benefit

Flood control benefit is generally defined as the reduction of potential flood damage attributed to the designed works. The reduction is obtained as the difference between the estimated flood damages under the with- and the without-the-project situations.

A study on annual average benefit to accrue by implementing the project has actually been carried out in the following flow:

(1) Estimate of unit property value
(2) Identification of the relation between water level and damage
(3) Calculation of potential flood damage
(4) Estimate of annual average benefit

Estimate of Unit Property Value

Property in the study area mainly consists of building/house and its indoor movables which are vulnerable to flood damage. In accordance with the land use categories, and unit value per area (km^2) was estimated for building/house as follows:

Combination		Construction Cost (Peso/m^2)	Depreciation Ratio (%)	B-to-L* Ratio (%)	Averaged Value (Peso/m^2)
Density	Quality				
(Residential/Commercial)					
Low	High	4,500	62	40	1,120
Middle	Middle	3,500	45	50	790
High	Low	2,500	40	60	600
(Industrial)					
Middle	Low	2,500	40	50	500

* Sharing ratio of the building to the land including the surrounding road areas.

Indoor movables belonging to the industrial category are evaluated at 1,230 peso/m^2 on an average, but the value of movables in the residential/commercial category is not separately estimated in this study because it is considered to be in proportion to the value of immovables and the flood damage can be calculated by multiplying damage rates with the value of immovables.

Based on these unit values per area of each category, the average unit value of properties is estimated for each sub-basin, as tabulated in Table 6.4-8.

Identification of the Relation between Water Level and Damage

Flood damage is basically calculated by the following formula; [unit property value] x [inundated area] x [damage rate]. The relation between inundation water level and flood damage was identified in each sub-basin on the basis of the relation between height and property value which had been prepared by measuring the areas on the contoured maps.

The damage rates applied for this study area were set up with reference to the research on flood damage carried out in 1983, as follows:

Inundation Depth	Damage Rates	
	Houses	Indoor Movables
0-25 cm	0.043	0.038
26-50 cm	0.046	0.044
Above 50 cm	0.054	0.070

Note: All damage rates are against the value of houses.

The direct damage rates of industrial indoor movables are likewise analyzed with results of 0.025, 0.053 and 0.180 against the value of indoor movables for the same classification of inundation depth. Indirect damage such as loss of income and loss of sales accounts for about 40% of the direct damage.

Calculation of Potential Flood Damage

Inundation and flooding water levels calculated for several probable rainfalls or discharges are applied to the relation between water level and flood damage discussed above, under the flooding cases of 2, 5, 10, 20, 30, 50 and 100-year return periods for river water flooding and 2, 3, 5, 10, 30, 50 and 100-year return periods for inundation in the drainage areas.

Estimate of Annual Average Benefit

Based on the estimated potential damages for each probable rainfall or discharge, the annual average damage was calculated by the following formula.

$$B = \sum_{i=1}^{n} 1/2\ [D(Q_{i-1}) + D(Q_i)] \bullet [P(Q_{i-1}) - P(Q_i)]$$

where,

B	:	Annual average benefit
$D(Q_{i-1})$, $D(Q_i)$	:	Flood damage caused by the floods with Q_{i-1} and Q_i discharges, respectively.
$P(Q_{i-1})$, $P(Q_i)$	:	Probabilities of occurrence of Q_{i-1} and Q_i discharges, respectively.
n	:	Number of floods applied

The annual average benefit, defined as the reduction of probable damage under the with- and the without-the-project situations, was thus estimated for the proposed plan, i.e., 2.78 billion pesos in total, the breakdown of which is presented in Table 6.4-9.

6.4.7 Economic Evaluation and Environmental Assessment

Economic Evaluation

The optimum plan or the Master Plan has been evaluated from the economic viewpoint by figuring out the economic viability in terms of internal rate of return (IRR), benefit/cost ratio (B/C), and net present value (NPV). All the monetary calculations were based on the price level of October 1988, and the project life (for economic evaluation) was fixed until 2050 considering the durable life of the last structure to be constructed for the project.

(1) Economic Project Cost

The economic costs of the project are nominal figues that duly reflect the true economic value of goods and services involved. These costs were used only for the economic evaluation of the project.

Transfer items such as taxes and duties imposed on construction materials and equipment, including government subsidy and contractor's profit, were excluded from the elements of financial cost. It is assumed that about 10% of the financial construction cost is involved as the transfer items.

Land has to be acquired for project implementation, and its economic value is considered to correspond to the productivity foregone by the project, which is reflected by the price. The economic cost is thus estimated at 12,474 million pesos, consisting of 6,919 million pesos for river systems and 5,555 million pesos for drainage systems.

(2) Economic Viability of the Optimum Plan

The calculation of IRR, B/C and NPV was based on the annual cash flow that was prepared from the above-said economic cost and the annual average benefit discussed in Subsection 6.4.6 in accordance with the implementation schedule or annual disbursement schedule (refer to Table 6.4-10). A discount rate of 15% was applied for the calculation of B/C and NPV. The economic viability of the optimum plan was thus figured out as follows.

- IRR : 17.3%
- B/C : 1.18
- NPV : 538 million pesos

(3) Project Justification

Social infrasturcture projects such as flood control and drainage improvement works are in general put into implementation even at the lower IRR, compared with other productive projects. The Master Plan shows a very high viability of 17.3% in IRR, likewise resulting in high values of B/C and NPV, for the conceivable reason that the study area will be remarkably urbanized in 2020, and thus social needs for flood prevention will augment to a maximum degree.

In this context, the Master Plan can be justified from the economical and social viewpoints to take a next step in accordance with the proposed schedule.

Environmental Assessment

(1) Method of the Environmental Impact Assessment (EIA) in the Master Plan

The main purpose of the EIA in the Master Plan is to identify initially whether the proposed works may cause crucial or significant effects on the environment. So, it is considered that a checklist method is an appropriate tool to attain the purpose mentioned above. Checklist items are selected by the Study Team taking into account of the guidelines prepared by the GOP and ADB.

(2) Result of EIA for the River Flood Control Works

A result of EIA for the river flood control works is summarized in Table 6.4-11.

The flood control works proposed in the Master Plan mainly consist of river improvement works, which may bring about betterment, though silightly, of river water quality by increasing the flow capacity. As for the other environmental effects such as aesthetics and landscape, such works will contribute much to more preferable scenery by improving landscape directly and drainage indirectly. Indeed accessibility to the river channels might be worsened, but judging from the present river utilization, its adverse influence is so small that there is no needs to take it into account.

Flood control works for the Pasig-Marikina River include large-scale structures such as Marikina Control Gate Structure (MCGS) and Marikina Dam which may give environmental effects, in addition to the above-said river improvement works. The conceivable problems caused by MCGS are the lake water rising of Laguna and the impairment of navigation for small boats. The Laguna lake water would rise by only 15 cm even when the design discharge with a 100-year return period flows down, and the lake water can be lowered more rapidly by 35 cm in case of a 40-year return period flood by the improvement of the Napindan River and the reverse flow of the Mangahan Floodway. As for navigation, small boats, in general, do not pass at the time of big floods and the gate of the MCGS is closed only at the time of a big flood. The water level in the immediate upstream of the MCGS would rise to a maximum of only 30 cm in a significant portion of 2.0 km by the construction of the MCGS. This can coped with a small scale embankment works, and no serious influence on the environment thereabout is anticipated. Since the Marikina Dam of a concrete gravity type is proposed only for the flood control purpose, the resevoir will not store water except for the flooding time, with a result of no deterioration of water quality of the river. However, construction of this dam will require resettlement of about 600 families.

(3) Result of EIA for Drainage Improvement Works

The result of EIA for drainage improvement works is summarized in Table 6.4-12.

Drainage improvement works consist of channel improvement, construction of ring dikes and installation of gates. Smooth and speedy drainage, expected by the channel improvement, may contribute much to the betterment of water quality as weel as to improvement of scenery. Gates are usually open and only during a flooding time operated. Hence, no influence on the fauna/flaura is expected by gate installation. Though construction of ring dikes may casue an inconvenience in accessing to the water shore, the environmental condition will be much improved by the ring dikes, in comparison with the situation flooded by the river water.

CHAPTER 7. FEASIBILITY STUDY OF PRIORITY PROJECT

7.1 Identification of Priority Area/Project

Priority areas/projects for the feasibility study were selected within the framework of the Master Plan on the condition that the areas are presently suffering from flood damage and the appropriate countermeasures are urgently required to be constructed in ten years. The selection was made on the basis of economic viability and the present land use conditions. Consideration was given also to the equal distribution of annual construction cost.

The results of the study on economic viability using the B/C ratio are shown in Table 7.1-1. According to the results, the value of B/C is almost the same for all the rivers. As for the drainage improvement, the values are higher for Manila and Suburbs, East and West of Mangahan, and Malabon-Navotas.

The drainage capacity in Manila and Suburbs is already of a certain degree of safety and this will be upgraded under the 14th OECF Loan. Therefore, the required urgent drainage improvement works and the related river improvement works are for the East and West of Mangahan and the Malabon-Navotas areas. It is noted here that the term Malabon-Navotas Area refers merely to the administrative boundary of the two municipalities and the objective area for drainage improvement is defined as the specific areas in Malabon-Navotas that are extremely vulnerable to flood damage.

On the consideration that the Pasig-Marikina River runs through the core of Metro Manila and that flooding from the river would cause tremendous damage to the urban areas, the importance of securing the core of Metro Manila from river floods is very high from both the economic and social viewpoints. This river can be divided into the upstream and downstream of the Mangahan Floodway from the viewpoint of land use condition along the river, and a higher priority should then be placed on the section downstream from the Mangahan Floodway which runs through the heavily congested urban area.

From the above considerations, the selected priority projects are recommended as follows.

- Drainage improvement of East and West of Mangahan;
- Drainage improvement of Malabon-Navotas area (First Phase); and
- River improvement of the Pasig-Marikina downstream of Mangahan (excluding San Juan River)

7.2 Drainage Improvement in East and West of Mangahan

7.2.1 Study on Alignment of Lakeshore Dike

The east and west areas of Mangahan Floodway suffer from flood damage in almost every rainy season due to the inundation caused by the high water in the Laguna Lake and heavy local rainfall. To protect the area from lakewater inundation, construction of a lakeshore dike is indispensable.

The alignment of the lakeshore dike is a factor to determine the target area for the improvement of drainage facilities.

In this connection three alternative alignments which protect the areas higher than EL 10.5 m, 11.5 m and 12.5 m, respectively, in ground elevation as illustrated in Fig. 7.2-1 were studied.

The economic justification has been made under the two land use conditions, i.e., the present and future conditions in which the existing open spaces will be utilized as residential area with some reclamation works. As a result, the alignment which can protect the area higher than 11.5 m of ground elevation is justified as the optimum alignment of the lakeshore dike for highest economic effect in both the present and the future land use conditions.

7.2.2 Present Condition of Drainage Area

Topographical Features

The East and West of Mangahan Floodway consists of the low-lying land bordered by the Sierra Madre Range on the east, the Guadalupe Formation Lowland on the west, Pasig River on the north and Laguna Lake on the south. From the geological point of view, the area comprises the southern half of the Marikina Valley Alluvial Plain and urbanization is observed on the higher ground near the Pasig River, while fishpens and open spaces are observed in the lakeshore areas.

Lake and River Utilization

Fishing and fish culture are briskly conducted in the lake and along the lakeshore. Since the Napindan Channel connects the Pasig River and the lake through the navigation lock at the Napindan Hydraulic Control Structure, brisk navigation can be observed in the channel to transport commodities between the city of Manila and the lake or the areas along the channel.

The Mangahan Floodway is partly utilized for "kangkong" cultivation and also for navigation, though not so brisk because of the weir at the junction of the Pasig River and the floodway.

Drainage Related Facilities

Major drainage structures are not observed in this area, except for the privately installed ones. There are a number of creeks and rivers as shown in Fig. 7.2-2, which are functioning as drainage channels to drain storm water into the Napindan Channel and the Mangahan Floodway, or directly into the Laguna Lake.

7.2.3 Planning Conditions

Watershed

The target area for drainage improvements as defined by the proposed alignment of lakeshore dike is composed of nine subdrainage areas being divided from the topographiocal point of view. Four of them are located in the east of Mangahan Floodway and five are in the west of Mangahan Floodway. (Refer to Fig. 7.2-2.)

Improvement Scale and Design Discharge

The lakeshore dike will be constructed with an elevation of EL 15.5 m based on the design high water level of Laguna Lake corresponding to a 40-year return period. The drainage facilities are designed to cope with the flood of a 5-year return period.

The priority project is implemented in the first phase (design year: 2000) of implementation of the Master Plan in which the target completion year is 2020. Therefore, the flood of a 5-year return period estimated under the land use conditions at the year 2020 is, in principle, employed as the design discharge for the respective facilities.

However, the design discharge under the land use conditions at the year 2020 is far bigger than at the year 2000. Therefore, the discharge estimated under the land use conditions at the year 2000 can be used for facilities such as drainage pumps whose capacity can be enlarged easily without any work duplication.

Based on the above consideration, the design discharge for each of the channels and the facilities was decided as follows (refer to Fig. 7.2-3):

(a) Facilities planned by the design discharge estimated under the land use condition of the year 2020

- River and drainage channel
- Control gate and sluice
- Regulation pond

- River dikes
- Pump house

(b) Facilities planned by the design discharge estimated under the land use condition at the year 2000

- Pumping equipment

Water Levels of Laguna Lake

The design high water level of Laguna Lake was set at EL 13.8 m, which is equivalent to the 40-year return period water level as mentioned before.

The average water levels obtained from the records of water levels for the past 15 years were identified. In designing the lakeshore dike and other related facilities, reference was made to these average water levels.

Water Level	Elevation (m)
Annual Maximum	12.5
95-day	11.7
185-day	11.2
275-day	10.7
355-day	10.5

Premise for Land Reclamation Height

At the present land use conditions, there are open spaces in the area facing Laguna Lake, and they are always inundated by the Laguna lakewater in the rainy season. However, these spaces will be utilized as residential area after completion of the lakeshore dike. This process of urbanization will naturally involve reclamation to avoid flooding.

It is difficult to define the future land reclamation height at this moment. Since the topography of the subdrainage area is strongly related to the estimation of the required facilities, future reclamation height should be determined. On this sense, the height of the future reclaimed area has been assumed at EL 12.0 m, which is almost the lowest elevation of the existing urbanized area, under the consideration that the elevation of the newly reclaimed area will not be higher than that of the existing ones.

7.2.4 Study on Alternatives

From the viewpoint of topographic characteristics, a study has been made to formulate the optimum drainage system on such items as the availability of backwater dike, the integration of subdrainage areas, and the determination of pumping capacities.

Availability of Backwater Dike

There exist a number of rivers and creeks which pour into the Laguna Lake, and the drainage areas have different sizes, ground elevations and topographic conditions, depending on which it may be more economically advantageous to drain storm water by the mechanical drainage system without a backwater dike than in combination with a backwater dike, and vice versa.

Based on the above consideration, it is economically justified that Buli, Baho, Mahaba and Lower Bicutan should be improved by a combination of mechanical drainage and backwater dike; while, Antipolo, Taguig and Bicutan is by the mechanical drainage method only.

Integration of Subdrainage Area

The number of subdrainage areas may be reduced by integrating the areas, depending on the total construction cost of drainage facilities, i.e., the construction cost of pumping facilities can be reduced when a large capacity pumping station is integratedly provided, though the construction cost of a drainage channel increases when a bigger discharge is planned to be conveyed to the drainage site. From the above concept, the integration of the subdrainage area was studied.

As for east of Mangahan, there are four subdrainage areas divided by the Buli, Baho and Mahaba rivers. Since all of the subdrainage areas are surrounded by the backwater dike for the Buli, Baho and Mahaba rivers and the lakeshore dike, the integration of subdrainage areas in the East of Mangahan is impossible.

West of Mangahan has five subdrainage areas and it is divided into two areas by the Napindan Channel; namely, the area between Mangahan and Napindan which has two subdrainage areas, and the area between Napindan and Lower Bicutan River with three subdrainage areas.

It has been clarified that the separate drainage system to each drainage area in west of Mangahan is recommended for the reason of the lowest construction cost.

Determination of Pump Capacity

The lake areas below the elevation of EL 12.5 m will be the land area by the construction of the lakeshore dike, though actually these areas are, in the dry season, utilized as paddy field and/or remain as open space. A part of the newly created land area can be used for the construction of flood water regulation pond.

The combination of required pumping capacity and required regulation capacity of the pond has been studied by the least construction cost method. The optimum combination for each subdrainage area is shown in the following table. (Refer to Table 7.2-1 for details.)

Subdrainage Area	Pump Capacity		Regulation Capacity of Pond (m3)
	Specific Discharge (m3/s/km2)	Total Discharge (m3/s)	
EM-1	5.4	9	*
2	4.5	11	*
3	1.8	5	18,000
4	1.0	2	33,000
WM-1	5.0	46	*
2	2.3	12	138,000
3	2.9	20	183,000
4	3.2	45	258,000
5	2.2	6	63,000

* In view of the topographical and land use conditions, regulation ponds were not designed.

7.2.5 Features of the Optimum Plan

The main component of the optimum drainage plan in the East and West of Mangahan are construction works of lakeshore dike and drainage channels, improvement works of the related rivers and existing drainage channels, and installation of pump stations and drainage gates. The principal features of the required structures are presented as follows, and their locations are shown in Fig. 7.2-4.

(1) Lakeshore Dike

The lakeshore dike will be constructed on ground elevation of about EL 11.5 m. This is an earth dike made of borrow materials, the lakeside of which will be revetted for protection against lake waves. (Refer to Fig. 7.2-5.)

The dike will not close the wide channels such as Napindan, Mangahan Floodway, Mangahan Diversion and Lower Bicutan, but bridges will be installed over these channels for the maintenance and transportation. Sluice gates will be installed at small channels that will be closed by the dike, so that effective drainage by pumps can be expected.

Structure	Quantity	Dimension
Earth Dike (with revetment)	10,700 m	EL 15.5 m, 9.1 m in width, 4.0 m in height
Sluice Gate (with maintenance bridge)	5 sites	240 tons in total
Maintenance Bridge	4 bridges	240 m - 30 m in span length

(2) River Improvement

Dredging and diking will be carried out for the Napindan Channel in a bottom width of about 80 m (almost equal to the existing) to assure the flow of lakewater from the Laguna Lake to the Pasig River. Earth dikes will be constructed on lakeside portions with open spaces, while a concrete structure such as a parapet wall is proposed on densely populated portions near the Pasig River. The height is from 0.5 to 1.5 m above the ground elevation for both structures.

Baho, Buli and Mahaba rivers will be provided with only backwater dikes. It is advisable to execute dredging works for these rivers after the completion of improvement works in their upstream portions.

A diversion channel will be newly excavated along the Mangahan Floodway to drain the storm water in the East of Mangahan into the Laguna Lake.

Structure	Quantity	Dimension
Napindan River (dredging/diking)	5,242 m	Parapet Wall 2,495 m in length; Earth Dike 2,747 m in length, 80 m in bottom width
Mahaba River (diking)	2,400 m	40 m in width
Baho River (diking)	1,800 m	45 m in width
Buli River (diking)	1,600 m	45 m in width
Mangahan Diversion (excavation/diking)	3,800 m	80-60 m in width
Lower Bicutan River (dredging/diking)	800 m	15 m in width

(3) Drainage System

Dredging works will be carried out for the Taquig, Tipas and Antipolo rivers in a total length of 35,200 m. A number of open and closed channels will be newly installed, as shown in Fig. 7.2-4, in a total length of 18,300 and 1,450 m, respectively.

Nine pump stations are also proposed and six of them are provided with a regulation pond each (refer to Fig. 7.2-4). In addition to the sluice gates along the lakeshore dike mentioned above, nine sluice gates will be placed at the pump stations and the junction of rivers.

Structure	Quantity	Dimension
Channel Improvement	35,200 m	35-5 m in width
Open Channel Construction	18,300 m	15-5 m in width
Closed Channel Construction	1,450 m	3 m in width x 3 units
Sluice	9 sites	186 tons in total
Regulation Pond	6 sites	693,000 cum in storage
Pump Stations	9 sites	111.0 cums in total (under land use conditions at the year 2000)

7.2.6 Preliminary Design of Major Structures

Preliminary design of major structures was made on the basis of least construction cost method.

Lakeshore Dike

The optimum shape of the lakeshore dike is determined considering wave setup height by the lake water, availability of embankment material and construction method, and foundation settlement. Through the cost comparison study among several alternatives, a borrowed material dike with a revetted slope of 1:2 at the lakeside and a slope of 1:2 without revetment at the landside is proposed, providing a freeboard of 1.7 m. The crest of the dike is set at EL 15.5 m and its width is 9.1 m from the requirement of maintenance road. The typical cross section is drawn in Fig. 7.2-5.

Backwater Dike

As a connected dike to the lakeshore dike, backwater dikes are provided for Napindan Channel, the Buli, Baho, Mahaba and Lower Bicutan rivers. (Refer to Fig. 7.2-4.)

For the Napindan Channel, earth dike and parapet wall are provided for the lakeside stretch and for the landside stretch, respectively. In desiging the earth dike, a similar shape of the lakeshore dike is basically adopted. However, revetment is not provided at the water side and its dike crest is set at EL 14.6 m, only considering a freeboard of 0.8 m derived from the planning criteria by design discharge, since effect of wave setup by the lake water is not considered.

A reinforced concrete parapet wall is proposed in the urbanized area for the landside river stretch, where a revetted channel cross section having a 1:1 side slope is provided to protect from foundation failure of the wall.

Along the river courses of the Buli, Baho, Mahaba and Lower Bicutan, the same type of diking of the earth dike of the Napindan only is proposed at present, since river improvement plans in their upper reaches are not concreted.

Typical cross sections of backwater dike are shown in Fig. 7.2-6.

Drainage Channel

Since there are relatively lots of open space in East and West of Mangahan, trapezoidal type of cross section with a side slope of 1:2 without revetment is adopted for improvement of existing drainage channels and construction of drainage channels. Basically, excavated channel method without diking is proposed, providing a design water depth of 2 to 3 m. As for closed channel, R.C. box culvert with two or three rectangular cross sectional areas is adopted considering a design water depth of connected drainage channel. Main features and design condition of drainage channels are summarized in Table 7.2-2.

Pump Station

A submersible type pump is applied for the pump equipment which can be operated by a diesel generator, through the economical comparison study between a conventional type and a submersible type. In addition to the said power supply equipment, garbage removal equipment such as mechanical rake, belt conveyor and hopper, and concrete structures such as sand basin, surge tank and operation house are provided, accordingly.

A general layout of the pump station is presented in Fig. 7.2-7.

Regulation Pond

Six regulation ponds are provided beside the pump stations along the lakeshore dike. Each pond is designed to be excavated at a 3 m depth with a cut slope of 1:2 from the ground level. At the boundary of drainage channel and pond, an overflow section of concrete structure is placed to control the inflow water from drainage channel. A general arrangement of the regulation pond, pump station and sluice gate is shown in Fig. 7.2-8. Fig. 7.2-9 shows the schematic profile of the regulation pond, pump station and sluice gate.

Sluice Gate

Proposed sluice gates are classified into four types as follows:

Type	Site
Open channel type/appurtenant to pump station	2
Box culvert type/appurtenant to pump station	7
Open channel type/independent	3
Box culvert type/independent	2

Sluice gates mainly consist of concrete structure and steel roller gate. Open channel type sluice gate is adopted in the case that a large cross section area for sluiceway is required from the design discharge and/or navigation of vessel. While, a box culvert type sluice gate is installed when a relatively small size gate is required.

Main dimensions of fourteen sluice gates are tabulated in Table 7.2-3. Fig. 7.2-10 shows a typical layout of a sluice gate.

Bridges

To cross the Napindan channel, the Mangahan floodway, newly proposed Mangahan diversion and the Lower Bicutan River, four bridges with relatively long spans are planned along the lakeshore dike.